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Sex Differences in Clinical Outcomes Following Surgical Treatment of Femoroacetabular Impingement

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Background: Sex-based differences in clinical outcomes following surgical treatment of femoroacetabular impingement remain largely uncharacterized; this prospective, multicenter study evaluated these differences both directly and adjusted for covariates.

Methods: Hips undergoing surgical treatment of symptomatic femoroacetabular impingement were prospectively enrolled in a multicenter cohort. Patient demographics, radiographic parameters, intraoperatively assessed disease severity, and history of surgical procedures, as well as patient-reported outcome measures, were collected preoperatively and at a mean follow-up of 4.3 years. A total of 621 (81.6%) of 761 enrolled hips met the minimum 1 year of follow-up and were included in the analysis; 56.7% of analyzed hips were female. Univariate and multivariable statistics were utilized to assess the direct and adjusted differences in outcomes, respectively.

Results: Male hips had greater body mass index and larger α angles. Female hips had significantly lower preoperative and postoperative scores across most patient-reported outcome measures, but also had greater improvement from preoperatively to postoperatively. The preoperative differences between sexes exceeded the threshold for the minimal clinically important difference of the modified Harris hip score (mHHS) and all Hip disability and Osteoarthritis Outcome Score (HOOS) domains except quality of life. Preoperative sex differences in mHHS, all HOOS domains, and Short Form-12 Health Survey physical function component score were greater than the postoperative differences. A greater proportion of female hips achieved the minimal clinically important difference for the mHHS, but male hips were more likely to meet the patient acceptable symptom state for this outcome. After adjusting for relevant covariates with use of multiple regression analysis, sex was not identified as an independent predictor of any outcome. Preoperative patient-reported outcome scores were a strong and highly significant predictor of all outcomes.

Conclusions: Significant differences in clinical outcomes were observed between sexes in a large cohort of hips undergoing surgical treatment of femoroacetabular impingement. Despite female hips exhibiting lower baseline scores, sex was not an independent predictor of outcome or reoperation.

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

The effect of biological sex on outcomes following the treatment of femoroacetabular impingement (FAI) remains unclear. Recent literature has suggested a sex discrepancy in preoperative hip morphology and clinical presented with greater α angles and more severe hip pathology compared with female patients, but that female patients exhibited lower baseline scores for patient-reported outcome measures (PROMs)[1]. Several other studies have shown that

TABLE I Preoperative Demographic Characteristics and Radiographic Parameters

	Male Hips (N = 269)	Female Hips (N = 352)	P Value*
Age† *(yr)*	29.8 ± 11.6	29.9 ± 12.1	0.955
Body mass index† *(kg/m²)*	26.1 ± 4.4	24.1 ± 4.6	**<0.001**
Body mass index ≥30 kg/m²‡ *(%)*	17.1%	12.3%	0.088
Bilateral procedure‡	14.9%	8.50%	**0.013**
UCLA activity score, 9 or 10‡	51.6%	30.1%	**<0.001**
Follow-up duration† *(yr)*	4.5 ± 2.5 (1-9.6)	4.1 ± 2.3 (1-9.8)	**0.020**
Acetabular inclination† *(°)*	5.9 ± 5.8	5.1 ± 7.2	0.190
α angle† *(°)*	68.0 ± 10.9	58.7 ± 11.7	**<0.001**
Lateral center-edge angle† *(°)*	30.2 ± 6.9	29.6 ± 7.3	0.310
Pain chronicity‡			0.850
<1 year	32.7%	33.2%	
1-5 years	56.5%	57.4%	
>5 years	10.8%	9.4%	

*P values were calculated with use of 2-tailed t tests for continuous measures and chi-square tests for proportions. Bolding indicates significance. †The values are given as the mean and standard deviation; follow-up duration also includes the range in parentheses. ‡The values are given as the proportion of patients.

TABLE II Concomitant Surgical Procedures and Intraoperative Disease Characteristics

Procedure and Disease Characteristic	Male Hips (N = 269)*	Female Hips (N = 352)*	P Value†
Treatment			
Labral repair	60.6	55.1	0.171
Labral debridement	29.4	31.8	0.512
Acetabular chondroplasty	72.9	46.6	**<0.001**
Acetabular microfracture	18.2	3.1	**<0.001**
Femoral head chondroplasty	9.3	6.0	0.117
Femoral head microfracture	3.0	0.6	**0.018**
Pathology			
Acetabular cartilage grade			
Normal	8.6	20.5	**<0.001**
Malacia	19.0	19.9	0.772
Debonding	15.6	36.4	**<0.001**
Cleavage	39.0	18.4	**<0.001**
Defect	17.8	4.8	**<0.001**
Femoral head cartilage grade distribution			
Normal	74.3	82.5	**0.016**
Malacia	20.9	9.5	**<0.001**
Debonding	0.0	0.3	0.377

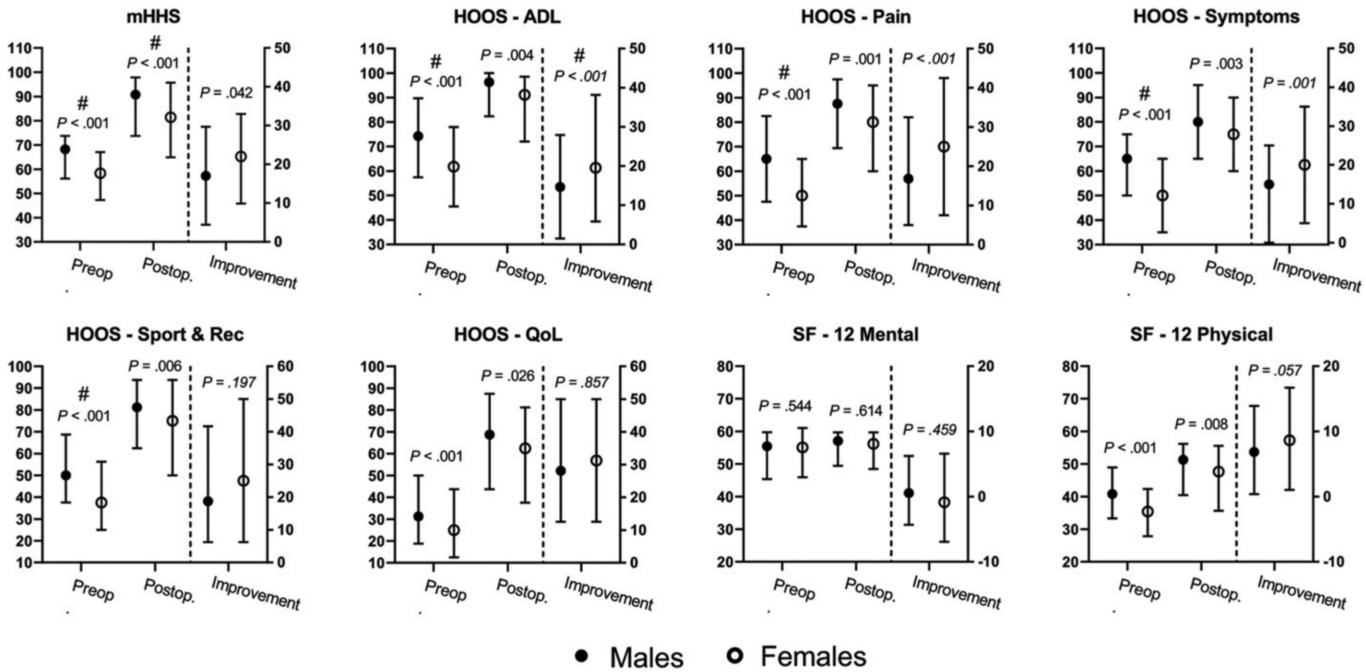

Fig. 1

Descriptive summary of preoperative and postoperative PROM scores, as well as improvement in PROM scores, between sexes. Data are presented as the median, and error bars indicate the interquartile range. Improvement is represented as postoperative score – preoperative score. # indicates that the difference between sexes exceeded the MCID.

intra-articular disease severity[2-4]. Despite these observations that male patients typically experience more severe disease, recent studies have shown that female patients have a higher overall incidence of FAI[5-7].

Prior literature demonstrated that female patients exhibited inferior clinical outcomes and a greater incidence of clinical failure[8,9], whereas other studies have demonstrated equivalent outcomes between sexes[10,11]. There is a paucity of high-quality, well-powered data on the discrepancies in outcomes between sexes following surgical treatment of FAI. Most of this literature comprises retrospective studies with relatively low patient numbers or studies that only performed direct comparisons without adjustment for confounding covariates, limiting the ability of these studies to identify sex as an independent predictor. The purpose of the present study was to assess whether sex is an independent predictor of outcome following statistical adjustment for relevant covariates in a large, prospective, multicenter cohort. We hypothesized that no differences in outcomes would be observed between male and

copy, hip arthroscopy with a limited anterior approach, and surgical hip dislocation, and outcomes were assessed at a minimum of 1 year postoperatively. Patients who underwent an

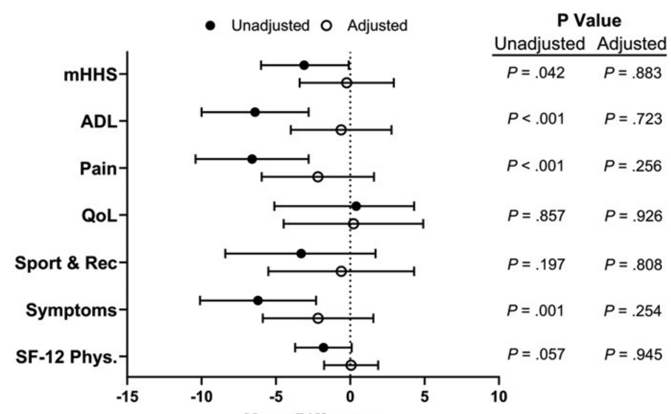

TABLE III Statistical Interaction Between Preoperative PROM Score and Sex ➤

	mHHS		HOOS Subscale		
			ADL		Pain
	β (95% CI)*	P Value†	β (95% CI)*	P Value†	β (95% CI)*
Model 1 (all covariates)					
Preop. PROM score	0.47 (0.38, 0.57)	**<0.0001**	0.34 (0.20, 0.48)	**<0.0001**	0.17 (0.05, 0.29)
Sex	0.24 (−2.9, 3.4)	0.715	0.61 (−2.8, 4.0)	0.723	2.1 (−1.6, 5.9)
Model 2 (all covariates except preop. PROM score)					
Preop. PROM score	—		—		—
Sex	3.6 (0.21, 6.9)	**0.037**	6.0 (2.3, 9.6)	**0.001**	7.68 (3.8, 11.5)
Model 3 (preop. PROM score and sex only)					
Preop. PROM score	0.56 (0.46, 0.65)	**<0.0001**	0.46 (0.38, 0.53)	**<0.0001**	0.44 (0.35, 0.52)
Sex	0.48 (−2.4, 3.4)	0.746	−0.57 (−3.8, 2.6)	0.725	0.46 (−3.1, 4.0)

*The values are given as the estimate, β, with the 95% confidence interval (CI) in parentheses. "All covariates" indicates the covariates listed in Supplemental Table 1 (see Appendix). †P values were calculated with use of multivariable linear regression models of the absolute postoperative PROM score. Bold indicates significance.

isolated limited open anterior approach (n = 12) or anteverting periacetabular osteotomy (n = 10) were not included in the current study because of small sample sizes. In cases of isolated hip arthroscopy, an interportal capsulotomy was utilized, and capsular closure was generally not performed during the study period. Rehabilitation was performed at the discretion of the treating surgeon and included continuous passive motion in 72.0% of hips. Weightbearing was immediately allowed in 19.5% of hips (generally in those that underwent arthroscopic labral debridement), whereas weightbearing was delayed to 4 weeks in 59.9% of cases and to 6 to 8 weeks in 21.6% of cases.

Exclusion criteria were revision procedures, Legg-Calvé-Perthes disease, or a slipped capital femoral epiphysis. Standard-of-care radiographs were obtained, generally including an anteroposterior pelvic radiograph and a lateral view (45° Dunn/frog/cross-table). Relevant radiographic parameters were prospectively measured, with previously established interobserver reliability among investigators[12]. Intraoperative data were collected in a standardized fashion, including acetabular and femoral head articular cartilage grade, and acetabular labrum grade, with previously published interobserver reliability among investigators[13].

Data Collection and Outcomes Assessments

utilized to measure hip pain and function. Secondary outcomes included the Hip disability and Osteoarthritis Outcome Score (HOOS)[15], which was utilized to measure physical function across 5 categories (symptoms, pain, activities of daily living [ADL], function in sports and recreation, and hip-related quality of life [QoL]), and the University of California Los Angeles (UCLA) activity score[16]. Because the UCLA activity score is nonlinear, scores were stratified into 2 categories (i.e., from 1 to 8 and from 9 to 10) in order to ascertain the level of participation in competitive impact sports. Lastly, the Short Form-12 Health Survey (SF-12) version 2 was utilized as a measure of general health[17].

Statistical Analyses

Univariate comparisons of continuous demographic and radiographic variables between male and female hips were performed with use of t tests. Absolute preoperative-to-postoperative improvement in PROMs was assessed with use of repeated-measures analysis of variance with Bonferroni post-hoc tests. Proportions of nominal variables were assessed with use of the Pearson chi-square test. Absolute differences in improvement between sexes were calculated with use of t tests, and multivariable linear regression was utilized to calculate adjusted differences. The proportion of hips that improved by at least the

TABLE III (*continued*)

HOOS Subscale									
Pain	QoL		Sports and Rec.		Symptoms		SF-12 Physical		
P Value†	β (95% CI)*	P Value†	β (95% CI)*	P Value†	β (95% CI)*	P Value†	β (95% CI)*	P Value†	
0.005	0.28 (0.14, 0.42)	**<0.0001**	0.14 (0.02, 0.26)	**0.016**	0.28 (0.17, 0.38)	**<0.0001**	0.15 (0.06, 0.23)	**<0.0001**	
0.260	−0.22 (−4.9, 4.5)	0.926	0.60 (−4.3, 5.5)	0.808	2.2 (−1.5, 5.8)	0.254	0.06 (−1.7, 1.9)	0.945	
	—		—		—		—		
<0.0001	4.34 (−0.58, 9.3)	0.083	4.96 (0.22, 10.1)	**0.010**	7.5 (3.7, 11)	**<0.0001**	2.6 (0.56, 4.7)	**0.012**	
<0.0001	0.52 (0.41, 0.64)	**<0.0001**	0.40 (0.31, 0.49)	**<0.0001**	0.42 (0.33, 0.50)	**<0.0001**	0.55 (0.46, 0.63)	**<0.0001**	
0.796	2.3 (−2.1, 6.8)	0.299	3.1 (−1.5, 7.6)	0.189	0.71 (−2.7, 4.1)	0.685	0.20 (−1.6, 2.0)	0.824	

chi-square tests for direct differences and Cox proportional hazards regression models for adjusted differences. Covariate selection for the multivariable models utilized a 2-step process: first, a stepwise selection method with the Bayesian information criterion for covariate inclusion was employed, and second, select clinically-meaningful covariates relevant to FAI (i.e., preoperative α angle, preoperative lateral center-edge angle, and follow-up duration) and sex (to assess the study hypothesis) were forced into final models. The final covariates and the set of parameters considered are listed in Supplemental Table 1 (see Appendix). Significance was set at 0.05.

Results

Baseline Characteristics

Of 761 enrolled hips, 621 hips (585 patients) (81.6%) met the minimum follow-up requirement of 1 year and were included in the study. Data completion rates of preoperative and postoperative measures were 96.7% (range, 94.2% to 100%) and 94.7% (range, 93.1% to 98.6%), respectively. Demographic and radiographic data are summarized in Table I. The cohort included 352 female hips (56.7%) and 269 male hips (43.3%), and the mean follow-up (and standard deviation) was 4.3 ± 2.4 years (range, 1.0 to 9.8 years). Hip arthroscopy was utilized in 64.3% of hips (including 67.6% of female hips and 59.9% of male hips), while surgical hip dislocation was utilized in 35.7% of hips (including 32.4% of female hips and 40.1% of male hips) ($p = 0.046$). There was no difference in age between sexes ($p = 0.955$). There was no

male hips generally exhibiting more severe cartilage pathology. No significant differences were observed in labral pathology.

Postoperative Outcomes

The majority (74.1%) of hips had acceptable clinical outcomes (i.e., no revision or reoperation, no conversion to THA, and improvement meeting both the MCID and PASS for the mHHS). A total of 25 hips (4.0%) underwent conversion to THA, and 45 (7.2%) underwent a revision hip-preservation procedure.

Differences in PROM scores between sexes were observed both preoperatively and postoperatively, but the magnitude of this difference was considerably greater preoperatively compared with postoperatively (Fig. 1; see also Appendix Supplemental Table 2). Male hips had higher preoperative scores across all PROMs compared with female hips (all $p < 0.001$), except for the SF-12 mental component score ($p = 0.544$) (Fig. 1). For nearly all preoperative hip-specific PROMs, the difference between sexes was greater than the respective MCID. At the time of the latest follow-up, male hips also had significantly higher scores across all PROMs (all $p < 0.05$) except the SF-12 mental component score ($p = 0.614$). However, only the median male-female difference in mHHS exceeded the MCID.

Postoperatively, more male hips had a UCLA activity score of 9 to 10 (male hips, 49.4%; female hips: 35.6%; $p = 0.001$), indicating a higher rate of participation in competitive impact sports. Female hips showed a marginal preoperative-to-postoperative increase in the rate of participation in competitive impact sports (preoperative, 30.1%; postopera-

A

Proportion of Total (%)

	mHHS MCID	mHHS PASS	Composite Failure	Conversion to THA	Revision
Males	76.1%	73.8%	21.6%	5.9%	3.7%
Females	82.5%	60.6%	28.9%	2.6%	9.9%

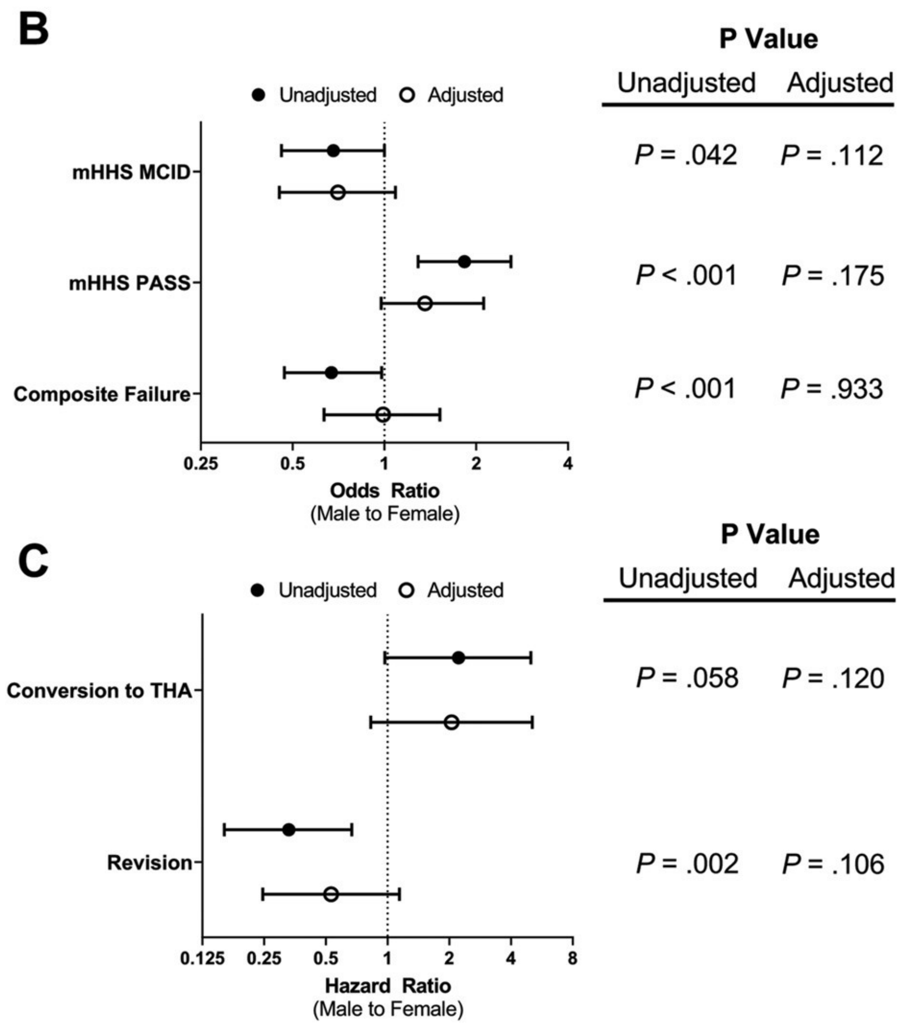

Fig. 3

Figs. 3-A, 3-B, and 3-C Adjusted and unadjusted differences in binary outcome measures between sexes, including descriptive proportions (**Fig. 3-A**), ORs (**Fig. 3-B**), and hazard ratios (**Fig. 3-C**). Composite failure was defined as conversion to total hip arthroplasty, revision or reoperation (excluding hardware removal), or failure to reach both the MCID and PASS for mHHS. **Fig. 3-B** Values of <1 represent greater odds among female hips compared with male hips.

models, the preoperative PROM score was identified as a significant negative predictor of PROM improvement ($p < 0.0001$ for all PROMs) and a significant positive predictor of the postoperative PROM ($p < 0.001$ for all PROMs). These results corroborate the finding that female hips exhibited lower preoperative and postoperative scores but exhibited greater improvement.

To elucidate the statistical interaction between sex and preoperative PROM score, the main regression model containing all covariates (Model 1) was compared with 2 additional regression models: Model 2, which contained all covariates except the preoperative PROM score, and Model 3, which contained only sex and the preoperative PROM score. In Model 3, sex was not significantly associated with any postoperative PROM (Table III); however, in Model 2, sex was significantly associated with all postoperative PROMs (all $p < 0.05$) except HOOS QoL ($p = 0.083$). These findings indicate a strong statistical interaction between preoperative PROM score and sex, and that the preoperative PROM score is the primary predictor of postoperative outcome.

Outcome States

Overall, 76.1% of male hips and 82.5% of female hips showed a preoperative-to-postoperative improvement in the mHHS greater than the MCID (odds ratio [OR] = 0.68; $p = 0.053$) (Fig. 3), indicating a trend toward a greater proportion of female hips reaching the MCID. However, following multivariable adjustment with use of logistic regression analysis, there was no significant difference between sexes in the likelihood of meeting the MCID for preoperative-to-postoperative improvement in the mHHS (OR = 0.70; $p = 0.112$) (Fig. 3). Similarly, although 73.8% of male hips and 60.6% of female hips met the PASS for the mHHS (OR = 1.83; $p < 0.001$) (Fig. 3), indicating that male hips were more likely to meet the mHHS PASS, multivariable adjustment showed that there was no significant difference between sexes in the likelihood of meeting the PASS (OR = 1.36; $p = 0.175$).

Additionally, 21.6% of male hips and 28.9% of female hips experienced composite failure (i.e., conversion to THA, revision, or failure to reach both the PASS and MCID for the mHHS), demonstrating a greater rate of clinical success among male hips; however, following multivariable adjustment, there was no significant difference between sexes in the odds of experiencing composite failure (OR = 0.99; $p = 0.933$). Male hips had a marginally higher incidence of conversion to THA ($p = 0.058$), whereas female hips were significantly more likely

demonstrated that female hips exhibited lower preoperative and postoperative PROM scores, but also had higher preoperative-to-postoperative improvement when compared directly with male hips without statistical adjustment. Concordantly, a greater proportion of female hips experienced improvement that met the MCID for the mHHS, but given the lower overall postoperative scores, a lower proportion of female hips met the PASS for the mHHS. Male hips had a higher incidence of conversion to THA, whereas female hips were more likely to undergo a revision surgical procedure. Despite these observed sex discrepancies, utilizing multivariable regression, we demonstrated that sex-based differences are predominantly a function of preoperative PROMs. After controlling for preoperative PROM scores, no differences in postoperative PROM scores, PROM improvement, clinical failure, conversion to THA, or revision were observed between sexes. Thus, clinicians should recognize that apparent differences in outcomes between sexes following surgical treatment of FAI are due primarily to differences in preoperative PROMs, and not specifically to sex.

The paradoxical finding in the present study was that although significant differences in clinical presentation were observed between sexes, including deformity severity and labral and cartilage pathology, outcomes appeared to be similar after controlling for baseline PROM scores. In a study on the role of sex and age on outcomes following hip arthroscopy, Frank et al.[9] reported that sex was significantly associated with the postoperative Hip Outcome Score Sport-Specific Subscale and mHHS after controlling for age and joint space width with multivariate analysis in a cohort of 150 patients. However, unlike the present study, Frank et al. did not control for preoperative PROM scores. In the present study, male hips exhibited greater hip deformity and more severe articular cartilage pathology, and thus had a higher incidence of concomitant surgical procedures, corroborating prior literature[2-4]. Female hips nonetheless exhibited inferior PROM scores and a greater incidence of revision. Our analyses demonstrated that the primary factor driving these differences was the preoperative PROM score. These results are similar to those reported in multiple previous studies, which have demonstrated the predictive capacity of preoperative PROM scores in determining clinical outcomes following surgical treatment of FAI[20-22] and other musculoskeletal conditions[23-26]. These findings also imply a direct discrepancy between a self-reported disability assessment and objective measures of disease, such as radiographic findings and cartilage pathology. To assess the basis of this discrepancy, some authors have postulated that preoperative symptoms of FAI are more closely related to mental arthroplasty[30], and rotator cuff repair[31]. The basis of this preoperative sex difference is still not understood, but extensive literature has characterized the greater incidence of clinical pain and higher overall pain sensitivity in female patients[32-35]. Thus, sex differences in preoperative PROM scores in musculoskeletal conditions are likely influenced heavily by pain. Previous studies have indicated that pain sensitivity and/or perception is a potential mechanism by which female patients exhibit pain-related sex differences[36,37], and other studies have characterized the physiological basis for pain-related sex differences[38]. As the PROMs utilized in this study all directly measure pain and pain-related disability, and as the pain subscale of the HOOS score had the greatest preoperative sex difference in our data, we concluded that intrinsic sex differences in pain sensitivity give rise, at least in part, to the differences in outcomes observed between sexes in our study.

Although the multicenter nature of this cohort should provide adequate generalizability, variability in surgical technique and in data collection are inherent limitations. Our results are based on a single follow-up at a mean of 4.3 years (range, 1 to 9.8 years), and our results may be affected by the wide range of follow-up duration. However, our large sample size relative to the number of covariates assessed in regression models permitted us to account for this range. Additionally, outcomes were assessed at a minimum follow-up of 1 year, rather than ≥2 years. However, the literature supports that minimal changes in outcomes are observed between 1 and 2 years following surgical treatment of FAI[18,39-41]. Additionally, the surgical treatment of FAI has continued to evolve since the study period. Although labral repair was frequently utilized, capsular closure (which is now more common) was not routinely performed during the study period. This study did not investigate other potentially important measures of hip function, such as range of motion and strength, and our conclusions are based primarily on subjective PROMs. Lastly, this cohort included both arthroscopic and open surgical hip dislocation procedures, both of which were commonly performed during the study period. In a propensity-matched analysis of this same cohort, surgical approach was shown not to significantly affect the outcomes of FAI surgery[42].

Conclusions

In this multicenter, prospective study with a large cohort of hips undergoing surgical treatment of symptomatic FAI, we found significant differences in preoperative and postoperative PROM scores between sexes. Following adjustment for the sex was not an independent predictor of outcome. Clinicians should recognize that the outcomes of surgical treatment of FAI are similar between male and female hips, and any overall differences between sexes are primarily related to differences in preoperative PROMs.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/G290). ■

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